

“Battelle Future Energy Resources Corp. gasification process - a status report”

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Battelle

Mr. Paisley received his B.S. in Chemical Engineering (1972) from the University of Cincinnati and performed Graduate Work in Chemical Engineering (1973-1975) at the University of Akron. Mr. Paisley joined Battelle in January, 1980. Prior to that time he worked at Bituminous Coal Research and the Babcock and Wilcox Research Center. He has over 25 years experience in gasification and fuels conversion processes and is also experienced in the areas of combustion, air pollution control, waste recovery, polymer recycling, and chemical process development. Mr. Paisley holds US Patents on 2 gasification processes and is also the inventor of a novel polymer recycling concept and a gas cleanup concept.

Since joining Battelle, Mr. Paisley has served as the Principal Investigator and Program Manager on Battelle's Biomass Gasification program. In this capacity he was responsible for all of the PRU tests, developing the sampling protocol, analyzing the experimental data, and designing the pilot plant scaleup from 4 to 12 tons per day capacity.

Mr. Paisley is on the Board of Directors of the Biomass Energy Research Association and received an R&D 100 award for the High Throughput Biomass Gasification Process in 1998.

The Battelle / FERCO Biomass Gasification Process – Status Update

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Battelle

. . . Putting Technology To Work

Biomass is an Attractive Energy Alternative to Fossil Fuels

- P Renewable resource
- P Readily available in most areas
- P Environmentally attractive
- P Can reduce CO₂ emissions

Industry / Utility Requirements for Alternative Fuels

- P Economical
- P Compatible with existing equipment
- P Minimal retrofit - conventional fuel backup
- P Environmentally attractive

Limitations to Biomass Use as a Fuel Source

- P Ash contains high levels of alkali
 - ▶ Ash fusion
 - ▶ Corrosion
- P Low energy density
- P Low power generation efficiencies

The Battelle Biomass Gasification Process

PDeveloped specifically for biomass

- ▶ High reactivity
- ▶ Low sulfur
- ▶ Low ash

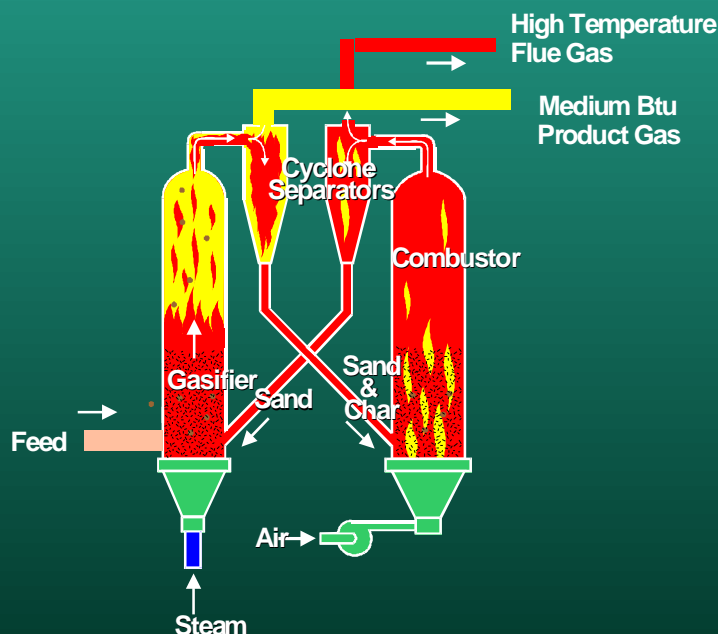
PProduces medium Btu gas without oxygen

- ▶ Low cost

PIs a high throughput process

- ▶ Reduced investment costs
- ▶ Easily incorporated into an existing site

The Battelle Biomass Gasification Process



The Battelle Biomass Gasification Process

P Separates gasification from combustion zones

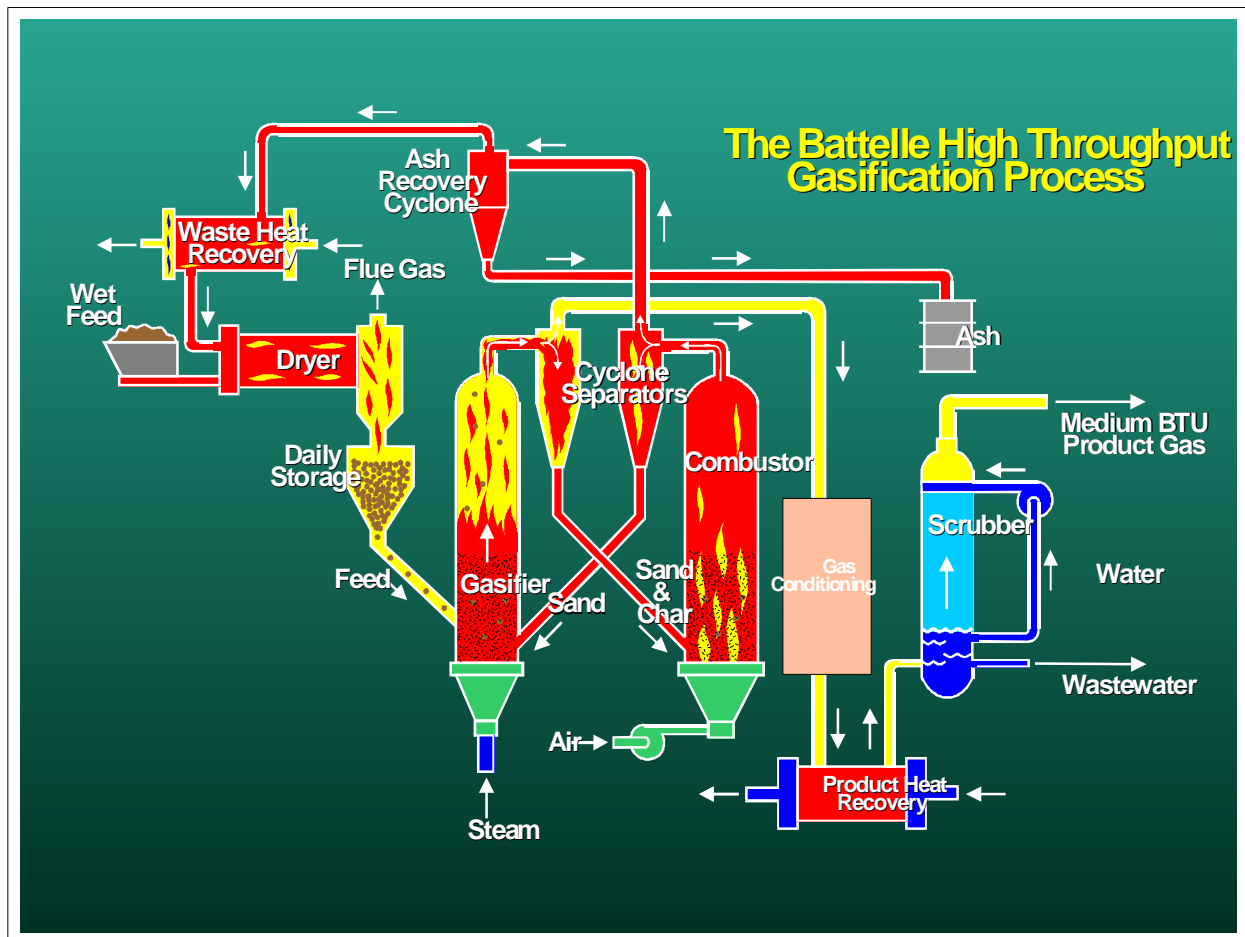
- ▶ Higher heating value gas
- ▶ High temperature flue gas available
- ▶ Product gas heating value independent of feed moisture or ash content

Development Status

P Extensive data base developed

- ▶ Woody biomass
- ▶ Herbaceous crops
- ▶ RDF

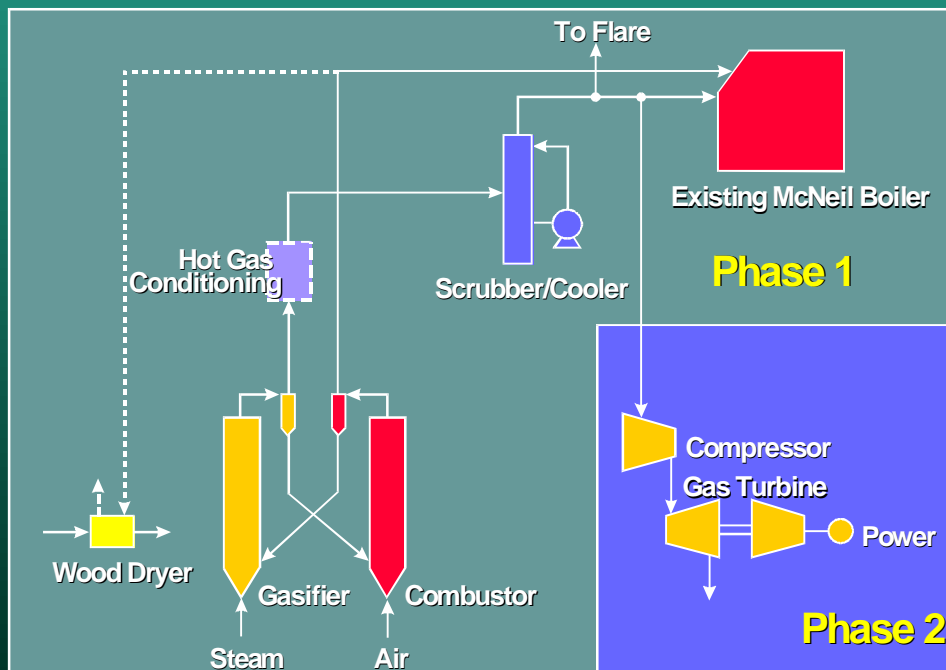
P Gas turbine coupled to PRU gasifier and operated



Characteristics of a Commercial Demonstration Site for Biomass Conversion Processes

- P Stable biomass supply
- P Interest in the technology
- P Capability to use the technology commercially
- P Economic advantages over other energy options
- P Representative commercial scale to eliminate “pilot plant compromises”

Vermont Gasification Program Simplified Schematic



What is the Vermont Gasifier Project?

- P First scale-up of the Battelle LIVG technology
- P Licensed to FERCO in 1992
- P Site Selection in 1993 at the McNeil Station
- P Phase I feasibility study starts in 12/93
- P Phase I detailed design completed in 3/95
- P September Phase II - EPC/Engineering under way

What is the Vermont Gasifier Project?

P 1996 Construction Period

- ▶ Site work starts in April
- ▶ December - engineering and procurement complete

P 1997 Startup and Operations

- ▶ Operator recruitment and training
- ▶ August/September essentially 100% complete
- ▶ October initial shakedown
- ▶ November - Hot solids circulation
- ▶ December - First wood fed - combustion mode

Power Generation Efficiency Comparison

P	Steam Temp.	Biomass to Power Eff.
Older steam power plant	300-400C	15-20%
"Modern" steam power plant	480C	25%
Gasification		
Gas turbine		
Combined cycle	NA	35-40%

McNeil Station Layout

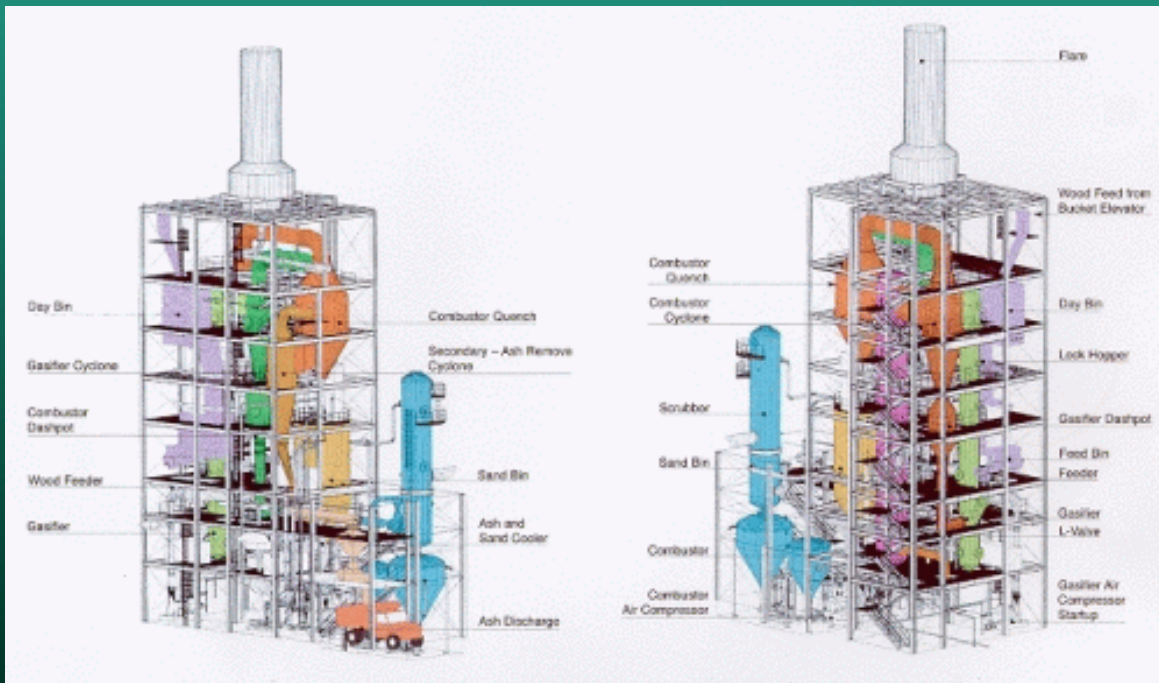


Vital Statistics

- P 200 ton/day wood feed
- P 40 MW_{th}
- P Atmospheric Pressure
- P Gasifier Bldg 44*32*105 ft
- P Scrubber Bldg 32*32*35 ft
- P Pipe Bridge to McNeil
 - ▶ Product Gas
 - ▶ Flue Gas
 - ▶ Steam from McNeil
 - ▶ DCS - link
 - ▶ Nitrogen and compressed air



General Layout of the VGP



Operational Issues and Challenges I

From September 1997 through June 1998

PHigh Temperature Refractory

- ▶ Shell - high temperature problems
- ▶ Vessel thermal leakage via grid supports
- ▶ Overbed burner vibration and refractory failure

PWood Feed System

- ▶ Change from dried McNeil furnish to mix with industrial wood
- ▶ Wood drier - located in Mass.
- ▶ Fuelyard management
- ▶ Lockhopper throughput

Operational Issues and Challenges II

From September 1997 through June 1998

PDCS - Distributed Control System

- ▶ Sensors
- ▶ Controls

PSolids Circulation Control

PScrubber Management

- ▶ Water level control
- ▶ Solids Management
 - High rate of sand attrition into scrubber
 - Silt not sludge characteristics
 - Pump modifications
- ▶ Organics accumulation

May-30 First Steam Gasification

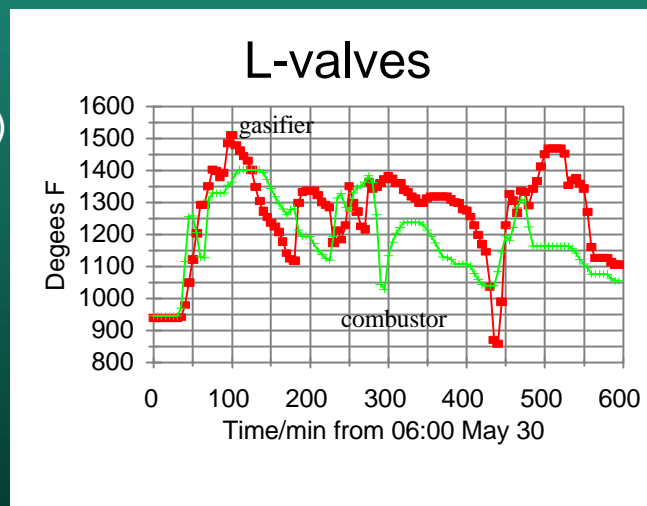
Partial Oxidation Gasification, February 22

PRuns Intermittent

- ▶ Mainly wood supply interruptions
- ▶ Low temperature (1300F or less)
- ▶ Far from design point (1500F, higher wood input)

PBest gas composition

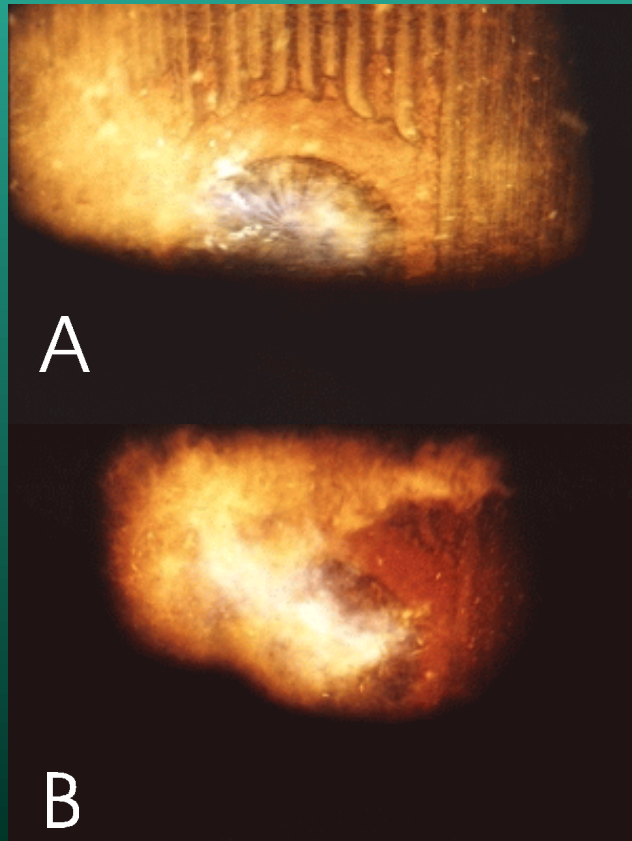
- ▶ CO 30%
 - ▶ H₂ 4.1%
 - ▶ CH₄ 4.4%
 - ▶ C₂H₄ 1.18%
 - ▶ C₂H₆ 0.34%
- Dry Heating Value = 180 Btu/Scf



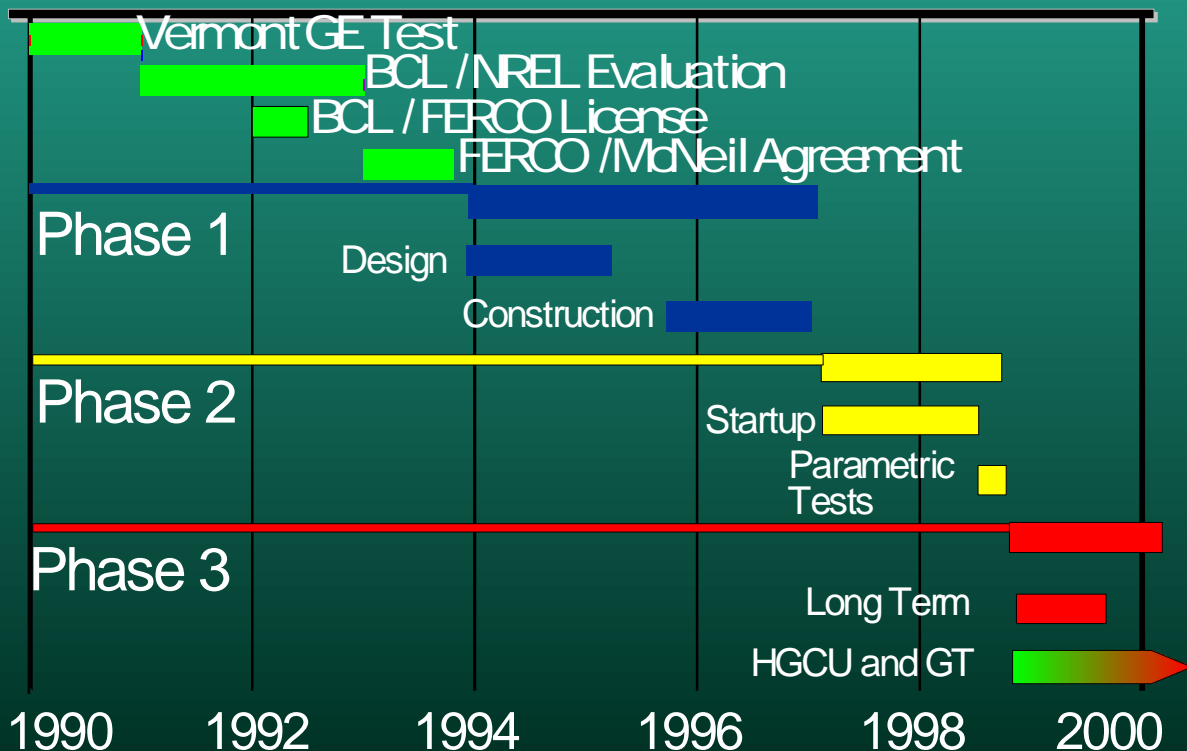
Flame at #2 Burner

Early stages of partial oxidation mainly natural gas burner -low luminosity short flame

Gasifier in operation at 60 Mbtu (NG pilot is 30 Mbtu). Increase in intensity and large increase in luminosity due to ethylene and tars in flame.



VGP - Development Schedule



Parametric Testing

Goals and Objectives

P Establish Performance Baseline

- ▶ Specification Fuel
 - Particle size
 - Moisture content
- ▶ Throughput
- ▶ Energy and Mass Balance

P Performance Envelope Determination

- ▶ Moisture limits
- ▶ Particle size
- ▶ Turn-up/Turn-down ratio
- ▶ Dynamic responses

Gas Conditioning for Power Generation

P Reduces or eliminates condensibles

P Adjusts H₂ / CO ratio of the gas

P Can reduce the requirements of a gas scrubber

P Can simplify or eliminate waste water treatment

Probable Turbine Requirements for Biomass Derived Fuel Gases

- P Total particulate <1 ppm at turbine inlet
- P Low alkali content
- P Burning characteristics similar to standard fuels
- P Heating value high enough to attain desired turbine inlet temperature

DN34 Identified as an Effective Hot Gas Conditioning Catalyst

- P Disposable
- P Low cost
- P Effective for both cracking and shift reactions
- P Resistant to coking
- P No pretreatment required

Supporting Research

- P Modify / adapt DN 34 catalyst system
- P Provide means to remove gas contaminants
- P Eliminate need for waste water treatment
- P Provide additional turbine operating experience

Typical Product Gas Analysis - Wood Feedstock

P H ₂	17.5
P CO	50.0
P CO ₂	9.4
P CH ₄	15.5
P C ₂ H ₄	6.0
P C ₂ H ₆	1.1
P Condensibles	0.5

Catalyst System Impact on Power Production

PEliminates compression problems

PWaste water treatment simplified

Projected Economics of a Gasification Cogeneration System

PCosts for a 818 ton per day plant

PGasifier	267 \$/kW	\$15 MM
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PGas & Steam turb.	770 \$/kW	\$43.1 MM
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PTOTAL	\$1037/kW	\$58.1 MM
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PAnnual operating cost		\$20.5 MM
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PPower

▶ Gas turbine	38 MW
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▶ Steam turbine	25 MW
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PPower cost		\$0.047
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Conclusions

- P The Battelle biomass gasification process provides an environmentally attractive means to utilize biomass as an energy source
- P Biomass power systems can be enhanced by use of hot gas conditioning
- P DN34 is an effective hot gas conditioning catalyst

Acknowledgements

- P We gratefully acknowledge the guidance and support of Ralph Overend, Rich Bain, and the staff at NREL during these evaluations.